Tropical cyclones continue to pose a significant forecast challenge for numerical weather prediction models, and vortex initialization is one of the factors in improving forecast accuracy. In the most basic (yet still practical) approach, a synthetic or “bogus” hurricane-like vortex can be generated and inserted into a model’s large-scale environment.

Kurthara et al. (1993) argued that the synthetic vortex should possess three properties to minimize dynamic adjustment and false spin-up/spin-down:

- structural consistency
- resemblance to the “real storm”
- compatibility with the numerical model

To ensure these qualities are enforced in the generation of tropical cyclone-like flows for model initialization, three general techniques, that work together or alone, have been developed:

1. data assimilation,
2. dynamic initialization, and
3. vortex Bogusing

This methodology provides an efficient vortex Bogusing scheme with many customizable parameters. A more detailed description and results can be found in Rappin et al. (2013).

2. Vortex Removal & Addition

The vortex removal technique closely follows that designed by GFDL (Kurthara et al. 1993, Kurthara et al. 1995). The figure below shows a flow diagram of the process, beginning with a model’s initial analysis. (Hurricane Florence 1986, from Kurthara et al. 1995).

In this framework, a moist, axisymmetric vortex is created and inserted into the model’s background environment in a dynamically consistent fashion. The radial and vertical structure can be specified, and a secondary circulation can also be generated. Below is an example of the “total”, “environmental”, and “initial” fields (wind vectors and perturbation hydrostatic pressure). (Hurricane Lilli 2002, from Rappin et al. 2013).

3. Configurable Parameters

A primary advantage of this technique is that many of the parameters that control the vortex removal and addition processes are easily adjustable. In the current version of the code (in Matlab and Fortran 90), there are approximately two dozen parameters the user can change. Some options depend on other options being set, but examples include:

- Storm center location (model-based or best-track)
- Radial structure (Mod-Rankine or Willoughby dual-exponential)
- Vertical structure (Gaussian decay or Emanuel)
- Secondary circulation (Emanuel or none)
- Boundary layer flow scheme (Foster similarity or Gaussian decay)
- Boundary layer depth
- Boundary layer eddy diffusivity
- Radius of maximum wind
- Storm depth
- Outflow temperature
- Radius of tropical storm winds
- Tangential wind decay exponent
- Gaussian decay rate constants
- Moisture enhancement

4. Model Experiments: Intensity

Setup of experiments on Hurricane Bill 2009:

- Nature run (NATURE: no bogusing)
- Control run (CONTROL: default bogus vortex)
- Initial moisture enhancement (MOISTPLUS: +10% RH at RMW)
- Influence of unbalanced secondary circulation (NOSEC: U=W=0)
- Varying eddy diffusivity value (K25: 0.45*CTRL, K100: 1.8*CTRL)

In all cases, the track forecast was very similar, and is not shown. The intensity forecasts (azimuthally averaged maximum tangential wind at lowest model level ~ 100m) are shown here. All synthetic vortex initializations shown here were conducted at 78 h into the nature run. The MOISTPLUS run is the only one that does not suffer from a significant initial adjustment period of vortex spin-down.

With inflated inner core moisture, regardless of secondary circulation and eddy diffusivity value, the adjustment time is greatly reduced.

5. Applications

The Fortran 90 version of the code runs ~150x faster than the original Matlab version, and is therefore suited for research as well as quasi-operational purposes:

- Idealized simulations, sensitivity studies
- Test observing strategies in OSSEs
- Basic plug-and-play vortex in Bogusing schemes
- A step in dynamic initialization schemes
- Ensemble of bogus vortices for data assimilation schemes


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